Gross Shell Structure of Moments of Inertia*

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We present a systematic study of the deviation of the moment of inertia from the rigid-body value in nuclei at high spins where the pairing correlations are expected to be negligible. In that case, the deviation from the rigid-body moment of inertia is a manifestation of shell effects in a finite quantal system.

Average kinematic moments of inertia are derived from the experimental energies of positive and negative parity yrast levels for cascades reaching spins greater than 15 $\hbar$ and usually much higher. Substantial deviations (called $\mathcal{J}_{sh}$) from the rigid-body values are found (see Fig.1), reaching $\sim$ - 65% near the N=126 spherical closed shell. The moments of inertia calculated by means of the cranked Woods-Saxon shell model without pairing show deviations similar to those found in experiment. We discuss the gross dependence of moments of inertia and ground-state shell energies on the neutron number in terms of the semiclassical periodic orbit theory (POT) which relates the quantum fluctuations to properties of a few periodic orbits in the potential considered. The gross dependence of the moment of inertia on neutron number can be deduced from the properties of these orbits.

Consideration of the simplest orbits (triangle, square, and five-point star) allows us to understand several features from a common point of view. The fact that near the closed shells the moments of inertia are much smaller than the rigid-body value, that they overshoot the rigid-body value around N=90, but that in most of the open shell they stay below it reflects the shell structure caused by the orbits in the meridian planes. The appearance of high-K isomers around N=100 and of high spin isomers near the closed shells is explained as a preference for rotation about the symmetry axis that is due to orbits in the equatorial plane. It also becomes evident why the moments of inertia in superdeformed bands are close to the rigid-body value.

Fig.2 shows the experimental ground-state shell energies. We see that the variations of ground-state shell energies and of $\mathcal{J}_{sh}$ as a function of neutron number have strong similarities: there are pronounced minima at the spherical magic numbers and oscillations between those. POT shows that only orbits which enclose the rotational flux of the frequency vector contribute to $\mathcal{J}_{sh}$. For each family of orbits which contribute to the shell moment of inertia, $\mathcal{J}_{sh}$ is proportional to the ground-state shell energy. We conclude that this is the reason why Figs. 1 and 2 are so similar: while both meridian and equatorial orbits contribute to the shell energy, the meridian orbits dominate the shell structure and are the main contributors. Since the nucleus rotates almost always around an axis perpendicular to the symmetry axis, it is also mostly the meridian orbits that contribute to $\mathcal{J}_{sh}$.

The relations between the shell effects in the ground-state binding energies, the nuclear deformations and the deviations of the moments of inertia from the rigid-body value are all due to the same periodic orbits.

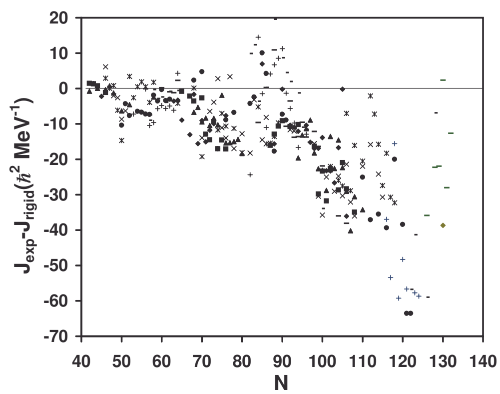

FIG. 1: Experimental deviations from the rigid-body moments of inertia as a function of neutron number for small and normal deformation. The proton symbols are the same as in Fig. 2.

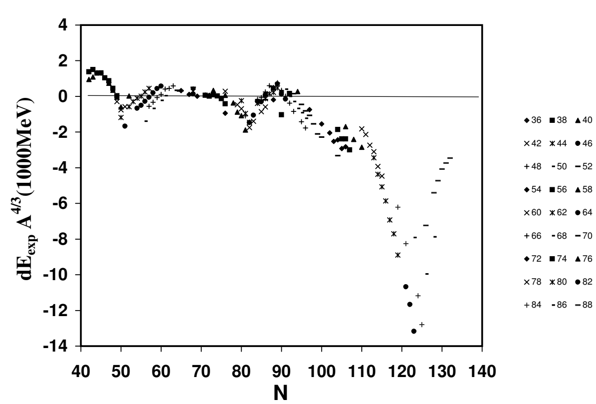

FIG. 2: Experimental shell energies at spin 0 as a function of neutron number.

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